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PROCEDURE FOR DETECTION AND MEASUREMENT
OF INTERFACES IN REMOTELY ACQUIRED DATA
USING A DIGITAL COMPUTER

by

K. H. FALLER

JANUARY 1976

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Kenneth H. Fallor

ERL Report No. 158

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PROCEDURE FOR DETECTION AND MEASUREMENT OF
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ABSTRACT

A technique for the detection and measurement of surface feature interfaces in remotely acquired data has been developed and evaluated. A computer implementation of this technique has been effected to automatically process classified data derived from various sources such as the LANDSAT multispectral scanner and other scanner-type sensors. The basic elements of the operational theory of the technique are described, followed by the details of the procedure. An example of an application of the technique to the analysis of tidal shoreline length is given with a breakdown of manpower requirements.

PROCEDURE FOR DETECTION AND MEASUREMENT OF INTERFACES IN REMOTELY ACQUIRED DATA USING A DIGITAL COMPUTER

I. INTRODUCTION

The linear measurement of the interface between two features is potentially very valuable, especially when coupled with measurement of the areal extent of the delineated features. One important measurement of this type that can be made is of land, water, and shoreline, and it was as a shoreline analysis tool that the technique to be described was developed.

Interfaces play a very important role in the physics, chemistry, biology, sociology, and politics of the world. Thermal energy is transferred across the boundary between a power plant cooling water discharge and ambient water; erosion takes place at the shoreline; it is across the land/water interface in the marsh that nutrients flow, as the inorganics for primary producers and the organic materials for higher marine life; at the interface between the farmland and small creek or stream, fertilizers and insecticides applied to the fields become agricultural runoff; it is at the boundary of the highway construction project with the swamp, wilderness, or tundra that the environmental impact of the highway is first felt; it is at the interface with industrial development that residential neighborhood quality frequently declines; it is at the flood plane boundary that the hazard to development suddenly changes; limits of ownership of land and mineral rights are often determined by particular land/water boundaries.

Given an understanding of the mechanisms involved in environmental dynamics, a definition of the interfaces involved becomes integral to a

quantitative analysis of natural and human-induced processes. Properly directed management of earth resources requires this type of analysis, and one important input to the analysis will come from monitoring the interface involved, detecting and measuring it. Because many of the boundaries found in nature are very extensive, and are also readily detectable in remotely acquired data, automatic analysis of aircraft and satellite data are particularly attractive as sources of information for environmental management.

The technique described in this document is designed to provide an accurate and inexpensive means of extracting information about interfaces from remotely acquired imagery. It has been used on satellite (LANDSAT) and aircraft data to detect and measure shoreline in marsh areas, demonstrating one application of interest to geographers and resource managers. While the basic elements of the theory of the interface measurement are presented here, a detailed analysis of the theory and application of the technique will be reported later. This report describes data which are appropriate for interface analysis, the steps in the procedure for extracting the interface measurement from the data, the products which are generated in the analysis, and concludes with a walk-through of an actual interface measurement problem. A breakdown of manpower requirements is given for this example.

II. DATA

Any kind of imagery which has been classified into two or more categories and is in a sampled, properly formatted form may be used in the interface analysis. The typical problem will involve the use of multispectral scanner data which have been processed by some pattern recognition technique to generate an image classified into categories which define the interface feature to be detected and measured. The data are not restricted to this type of imagery. Thermal scanner imagery can be analyzed to generate, for example, an image showing water of normal temperature and a thermal effluent plume, and the interface analysis technique can be used to measure the interface at the surface of the water between the plume and the ambient water for dispersion studies.

It is also possible to manipulate data which are in the form of maps or photographs. This type of data may be sampled and digitized to produce a map or image in a format suitable for processing by the interface analysis technique.

A sampled image is in the form of a series of small picture elements, often referred to as pixels. One may think of the image as a matrix with rows corresponding to the scan lines generated by the scanner, with the individual matrix elements being the pixels. The picture element has dimensions determined by the scanner and the platform; the separation of the center points of the pixels within a row of the matrix determines the "width" of the element, while the center to center distance between pixels in a column of the matrix determines the "height" of the element. Figure 1 illustrates the relationship of the sampled imagery to the scene which it portrays.

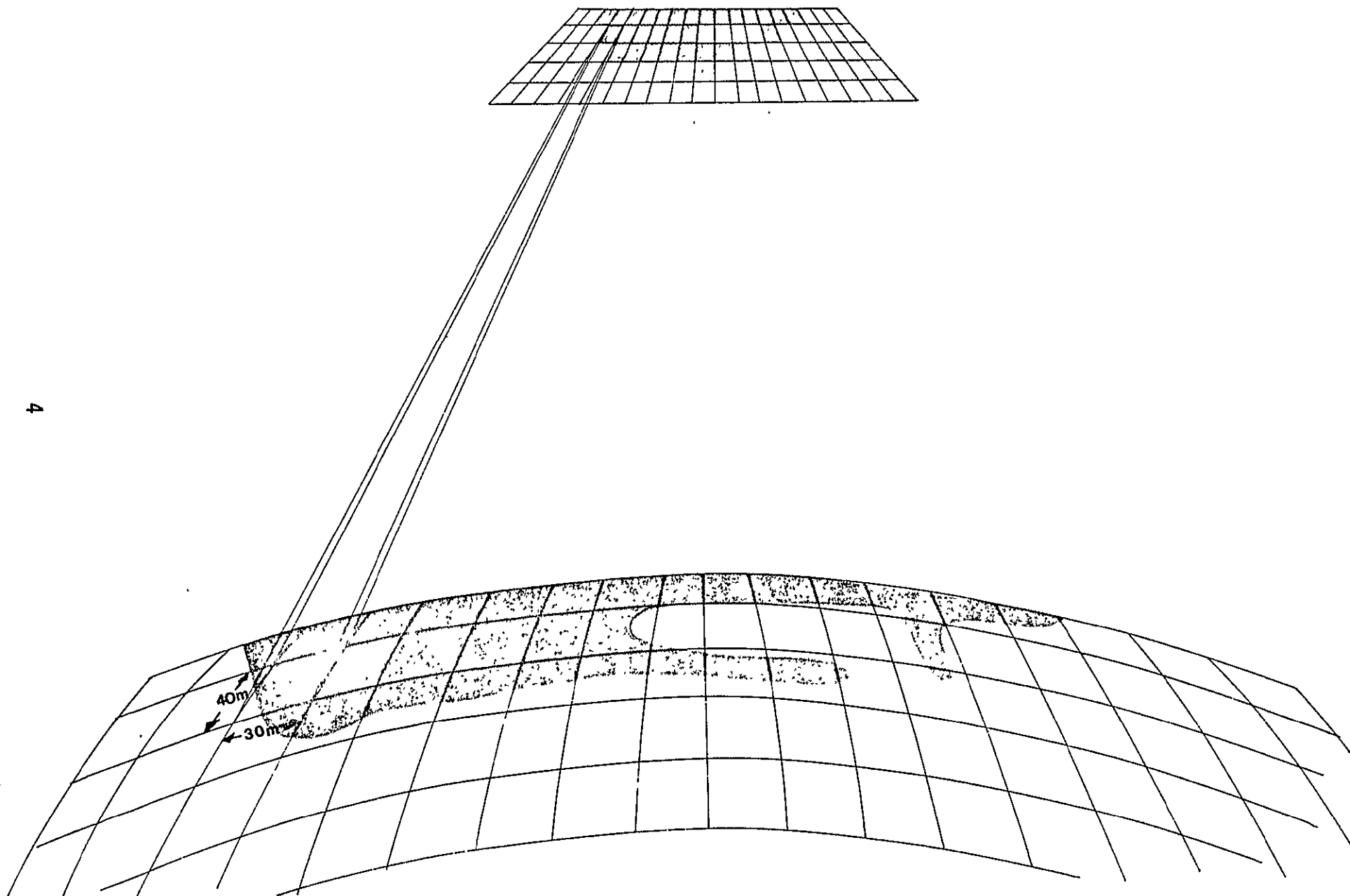


Figure 1. - Scanner image concept.

Scanner image (above) corresponds to the earth scene (below). Each element in the scanner data represents the average conditions of the area on the surface within the instantaneous field of view, which in this illustration is 30 meters by 40 meters.

III. THEORY

The description of the theory of operation presented here for the interface analysis technique is not intended to be exhaustive or fully comprehensive. A complete description and analysis of the theory will be the subject of a future report.

A. Interface Detection and Measurement

There are two basic problems which must be solved in an analysis of an interface in classified data: The interface must first be detected, and then it must be measured. These problems are treated separately in this report, but are in fact handled as one by the computer in the interest of maximum efficiency.

Just as the image consists of individual picture elements, the interface defined in the analysis is composed of discrete line segments known as interface elements. Interface is a linear phenomenon, whereas the picture elements are areal in nature. Consequently, the interface element is defined as the common edge of two picture elements which represent different classes. A single picture element may therefore have associated with it as many as four interface elements.

As the interface detection algorithm has been developed, only two classes define the interface. It is rather unusual for a two category product to be generated by standard pattern recognition analyses, so the many classes which may be present in the data must be grouped into super-classes. As an example, if one desires a measurement of the land/water interface in a swamp, ten classes

representing individual vegetation species or groups of species might be required to define "land" and two classes representing lake water and river water might define "water". The ten vegetation classes would then be grouped into the land super-class while the water classes would coalesce to give the water super-class. An additional vegetation class might represent floating vegetation, so in an analysis of shoreline length, one would group the floating vegetation with the water super-class. The remainder of this report will not be concerned with this grouping, but will consider the classified data as if it consisted of only two categories, although these may in fact be super-classes such as those just described.

The actual detection of an interface between the two classes is accomplished by examining the entire data set sequentially through a two pixel wide by two pixel high examination window. If there are two classes present within the window, then there must be an interface; if there is only one of the two possible classes present, then there is no interface. The window is scanned over the data, as illustrated in figure 2. The window is shifted to the right one element at a time, so that each pixel appears first at the lower right corner of the window, then as the lower left. After completing a scan across one row of the image array, the window is shifted down one to the next row of the matrix, and scanned again. The elements which previously appeared in the bottom row of the window then appear in the top row. Each element is passed over four times in a complete analysis of the data.

The contribution of an interface element to the total interface measurement is dependent on the orientation of the element. The

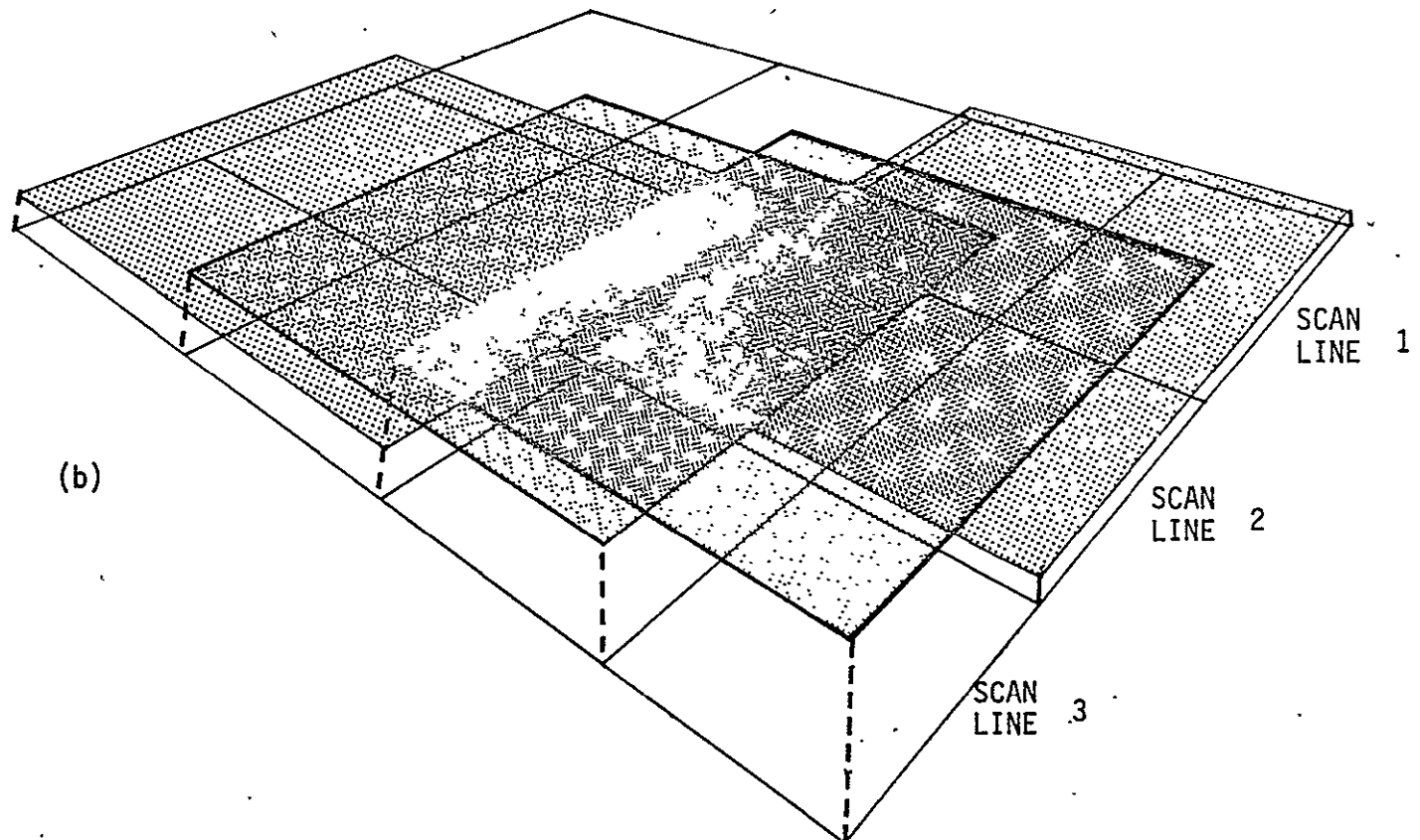
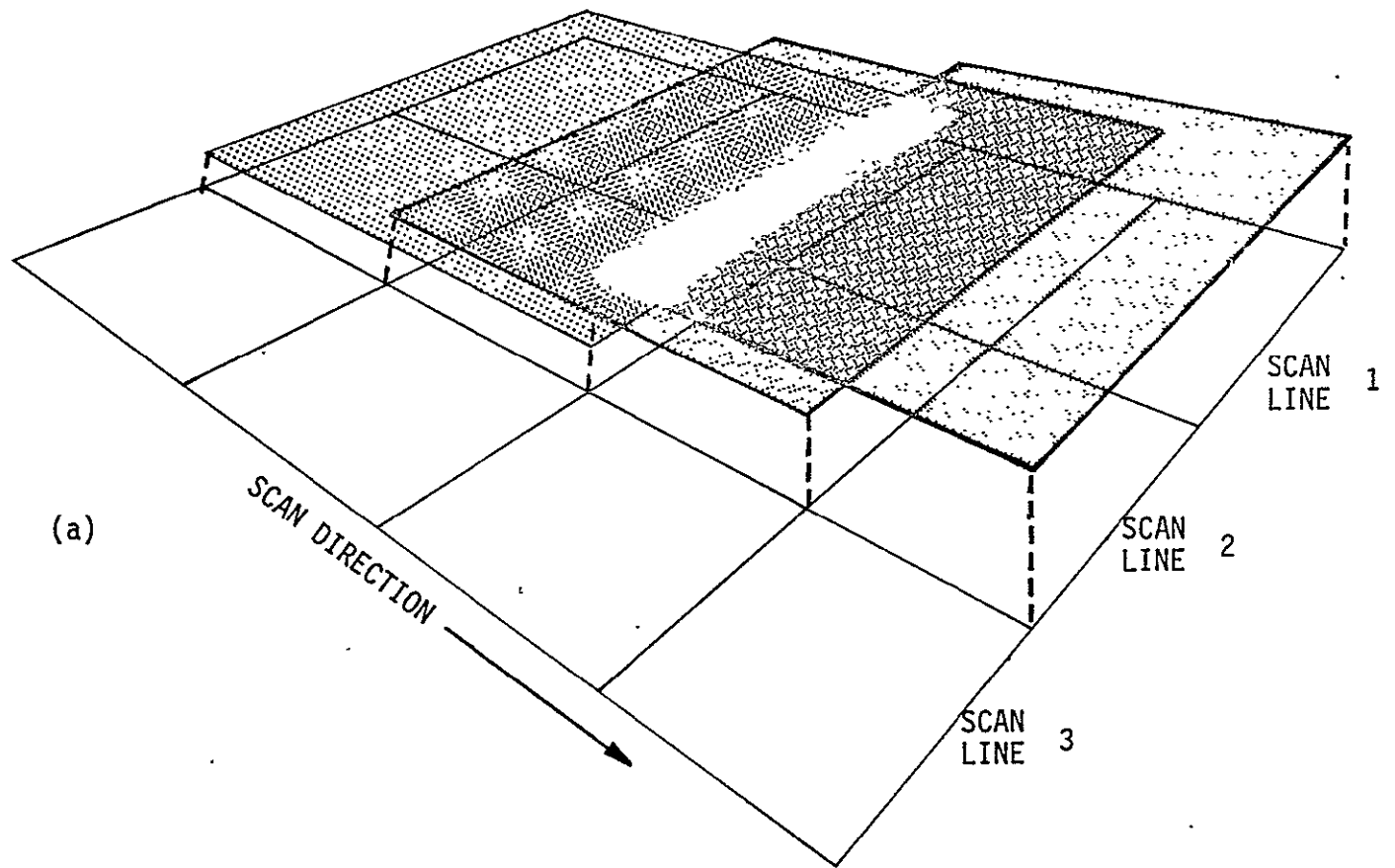
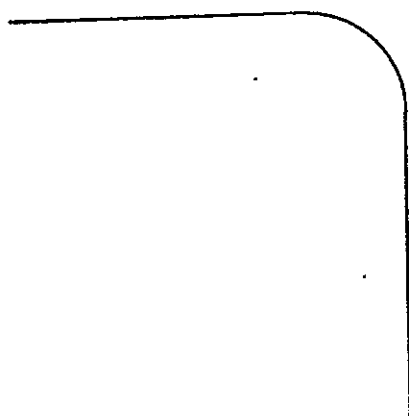


Figure 2. - Interface detection procedure.

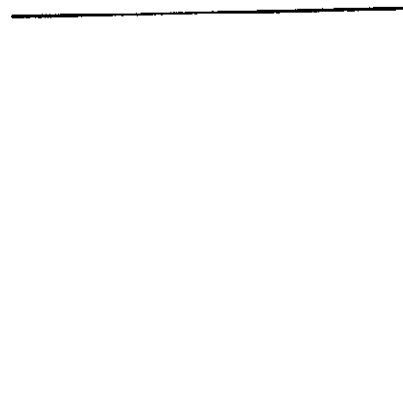
Four element examination window (shaded squares) is passed along scan lines 1 and 2 (a), then along scan lines 2 and 3 (b), overlapping one scan line. An interface is detected when two different classes are found within the window.

first case to consider is that of interface elements which are oriented either parallel ("horizontal") or perpendicular ("vertical") to the direction of the sensor scan. For these elements, the contribution is the respective dimension of the picture element itself. Two other cases present special problems. If a straight interface feature is oriented at an angle which is neither parallel nor perpendicular to scan direction, the feature will appear as a jagged line, constructed with alternating "horizontal" and "vertical" elements. The other situation arises with the sampling of smooth curves, where the finite sampling grid causes a smooth, rounded interface feature to appear as a sharp corner. Figure 3 illustrates the problem these two cases present. When either diagonal or corner type features are detected within the examination window, picture elements adjacent to the window are examined to determine which of the two types is actually present.

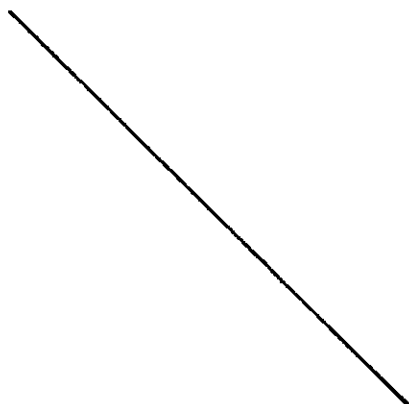
The diagonals are subdivided into three types, examples of which are shown in figure 4. The same elements surrounding the examination window which were used to distinguish the diagonals from the corners also determine the type of diagonal, as determined by the slope of the indicated interface feature relative to the sensor scan. The slopes for the three diagonal types are $2V/H$, V/H , or $V/2H$, where V and H are the picture element dimensions perpendicular and parallel to the scan direction respectively. The contribution to the interface length for each of the diagonal types is $\sqrt{H^2 + 2V^2}$, $\sqrt{H^2 + V^2}$, and $\sqrt{2H^2 + V^2}$, respectively. Because of the manner in which the scanning examination window reveals the interface elements, the presence of the first or third type of diagonal interface element



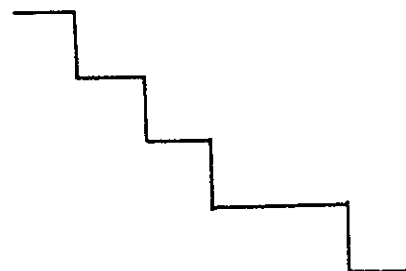
ACTUAL CURVE



SAMPLED CURVE



ACTUAL CURVE



SAMPLED CURVE

Figure 3. - Interface distortion.

Problems arise when interface features on the surface are curved, and when they are straight, but oriented neither parallel nor perpendicular to the scan direction.

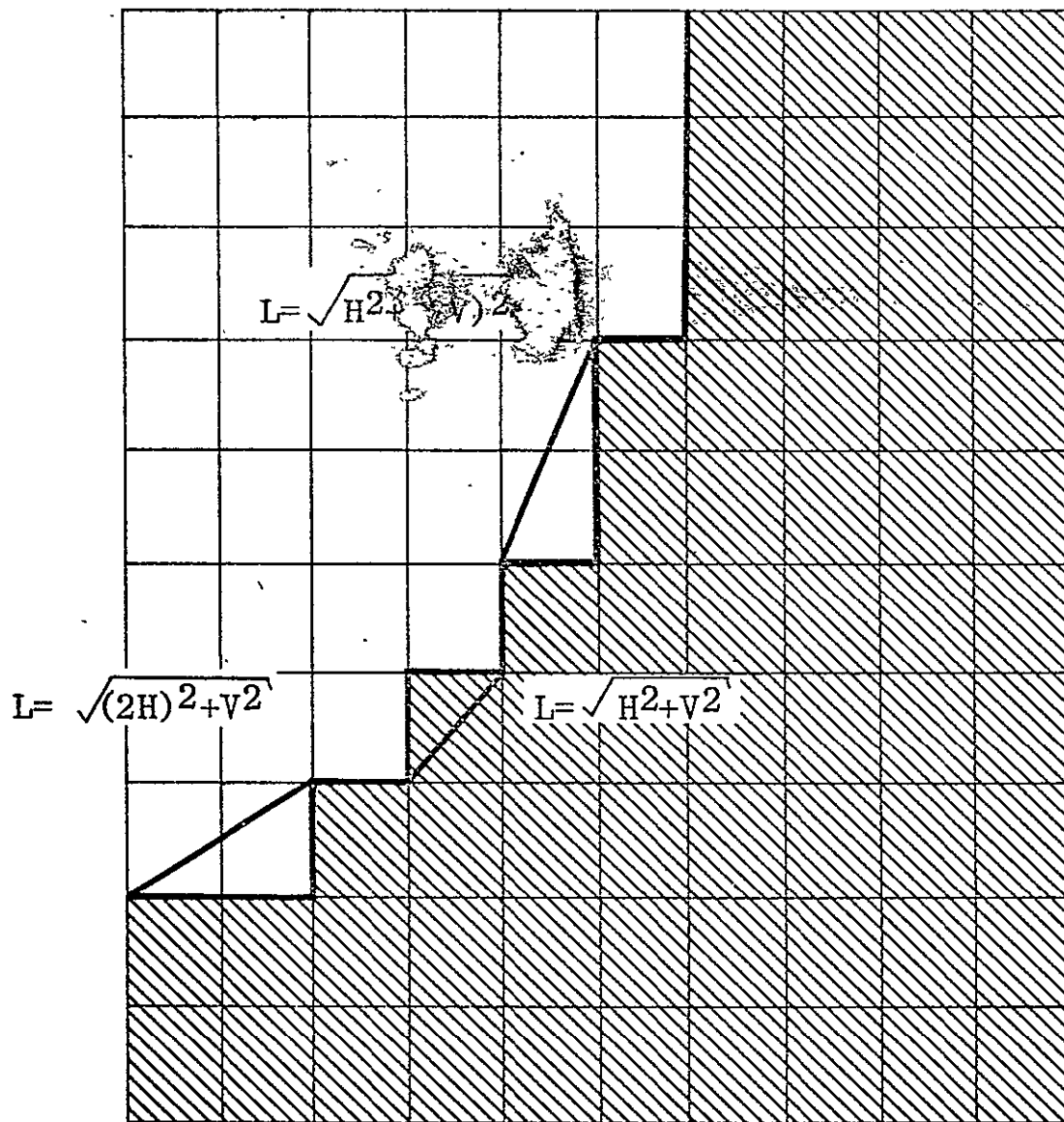


Figure 4. - Diagonal interfaces.

Three types of diagonal interface elements are considered in the analysis, each with a unique contribution to the total length. The cross-track pixel dimension is H (along the scan line) and the other dimension is V .

introduces an error into the total length being accumulated by causing an extra element to be detected and counted either along the scan line or perpendicular to it, so the appropriate correction is made when this occurs.

When examination of the pixels surrounding the basic examination window indicates that a curved surface feature has been squared off by the sampling, the contribution of this "corner" interface element is added to the total being accumulated. This contribution is computed as the sum of half of the picture element dimensions and one-fourth the mean of the perimeters of the ellipse which can be inscribed and circumscribed on the picture element. The $1/2 H$ and $1/2 V$ contributions are accumulated with the sums of the along scan line and across scan line interfaces. The additional length of the curve is computed from the relation

$$C = 0.60355 A E(k)$$

where E is the complete elliptical integral, $k = \sqrt{1 - B^2/A^2}$, and A and B are the longer and shorter pixel dimensions respectively.

B. Area Measurement

As the original classified data is being grouped into the super-classes, the number of elements of each super-class is accumulated by counting the picture elements which are being placed in it. At the completion of the processing of the data, the number of picture elements in each class is multiplied by the area of an individual element to give the total area of each super-class. This method of

area mensuration assumes that all geometric rectification has been performed during a preceding phase of processing.

C. Display Generation

It is usually desirable to generate a display of the results of the analysis to show the interface which has been detected and measured. This is accomplished by creating a third class (in addition to the original two super-classes) which represents the interface for display purposes only. When a picture element of the second class is found to be adjacent to an element of the first class, it is replaced by an element of the third, or interface, class. The modified display then shows the original data grouped into the two super-classes with the newly created interface class substituted for elements of the second super-class when they occur along the boundary between the two super-classes.

IV. PROCEDURE

The processing sequence which carries the original data into a display showing the interface between two classes and lists the interface length and area of each class is basically the same for the various types of data which are available and suitable for this work. The most commonly used scanner data thus far have been provided by LANDSAT, so the description of the Interface Analysis Procedure is directed toward that type data. The procedure is broken down into ten basic steps which are outlined in figure 5.

The analysis begins with a determination of the suitability of the data for the proposed task (step 1). The data are initially examined as a hard copy image or television-like display, at which time the investigator notes such factors as whether the area to be studied is completely included in the data set, whether clouds will interfere with the analysis, and whether the data appear to be of sufficient quality to distinguish the classes for which he requires the interface measurement. If the data set is found to be suitable for the task, the computer compatible magnetic tapes (CCT) are obtained.* All subsequent work makes use of these CCT's.

Steps 2 through 5 involve classification of the data into the various categories required to define the interface to be analyzed. Typical classification procedures are described in greater detail

*In the case of LANDSAT data, this involves acquiring the tapes from the Department of the Interior EROS Data Center or in certain cases from the Department of Agriculture, from the National Oceanographic and Atmospheric Administration, or from NASA, while in the case of aircraft scanner data, decommutation of the pulse code modulated (PCM) recorded signal from the aircraft tape is required to generate CCT's.

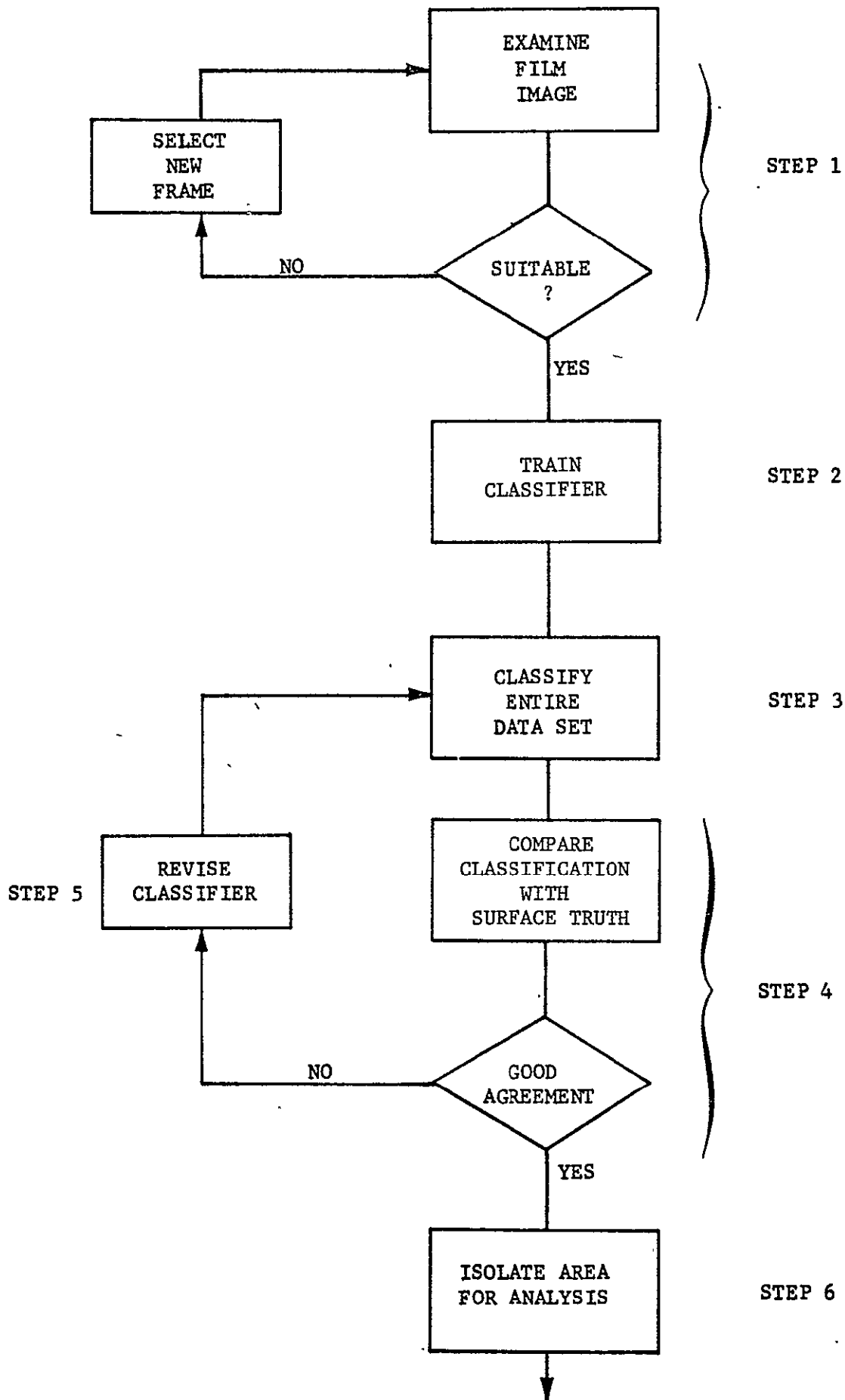


Figure 5. - Interface analysis processing flow chart.

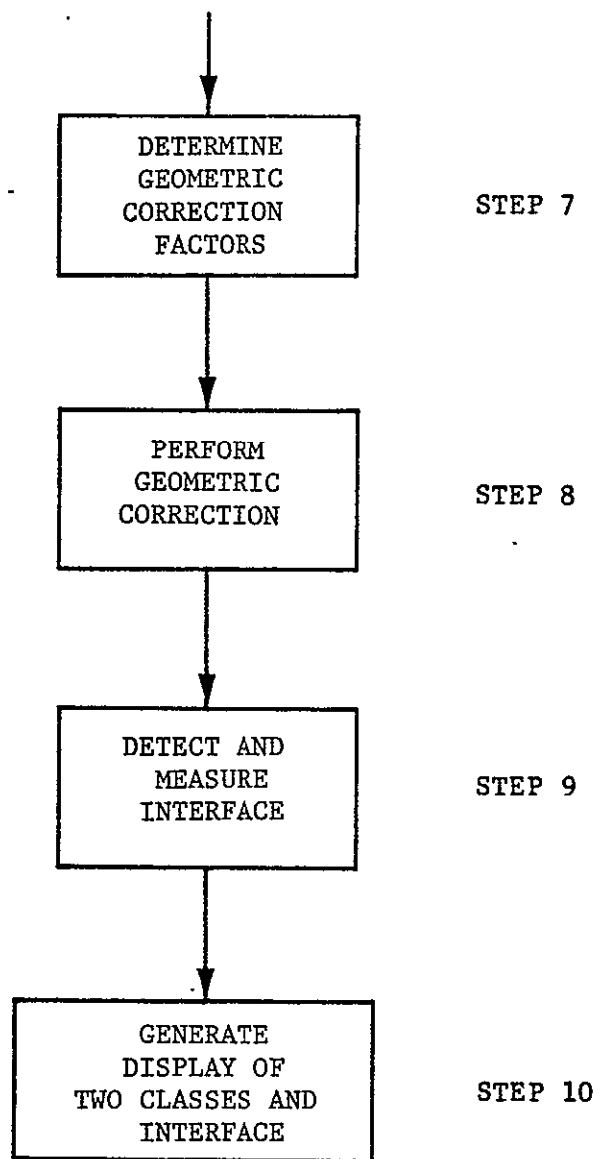


Figure 5 (continued)-- Interface analysis processing flow chart.

in other documents (e.g., Whitley, 1975), but the basic elements relevant to this analysis are described below.

Most classification work is based on spectral pattern recognition. The computer must be "trained" to recognize spectral signatures of the classes to be found in the data (step 2). These signatures are developed by an analysis of spectral data from areas known to be representative of the classes in general. These areas are referred to as training samples, as they are used to "train" the computer to recognize the spectral signatures; i.e., the characteristic spectral responses of the target categories. The entire data set is then processed by the classifier, with each picture element being tested against the spectral signatures developed from the training samples and categorized according to a decision rule which is normally built into the pattern recognition algorithm (step 3).

After a classified product has been generated, it must then be evaluated relative to surface truth information (step 4). This may consist of a comparison of the product with aerial photography which has been analyzed by a photointerpreter or with information acquired from actual field work. If the product matches the surface truth information with sufficient accuracy (which must be determined by the user for each application), the classification is complete. However, if there are an unacceptable number of errors in the classification, the input parameters of the pattern recognition software must be revised (step 5). The classification is repeated with the new parameters and the new product evaluated, and this procedure is repeated for each frame until an acceptable product is generated. The number of

repetitions is generally reduced with user experience. If, after extensive analysis of the data, it is determined that the data are not suitable for separating the desired classes, a new set of data may be obtained which will allow the classification to be performed accurately; or, in the worst case, the problem may be modified.

Step 6 in the interface analysis procedure is the isolation of the data upon which the analysis is to be performed. Normally, the data set will cover an area larger than the area of interest. For example, in the demonstration analysis presented later in this document, the problem was to measure the tidal shoreline. It was therefore necessary to eliminate all of the land/water interface along river banks, farm ponds, and so forth, where tidal flow was not present. The study area may be defined on a hard copy display of the classified data for reference in this step, in which all picture elements that are to be excluded from the analysis are reclassified into a unique category which is recognized as excluded by the final interface detection/analysis computer program. This is normally accomplished at ERL using the interactive Data Analysis Station (DAS) Update Program, but may be accomplished in whatever manner is best for the user.

The data which are generated by the ERL pattern recognition software are contained on magnetic tape in a particularly simple format. After a preamble containing information such as scan line number and length of scan line, each six bit character representing a picture element contains a number in the range of zero to 63 which corresponds uniquely to a category, with the number zero reserved for unclassified areas.

Excluded areas may be assigned a unique number, but all classes which are not grouped into either super-class are excluded. The super-classes are assigned a value of one or two internally by the Interface Analysis Program, while excluded areas are internally assigned the value three (3).

There is one restriction placed on the isolation in the current version of the software. The analysis begins with the first picture element included in either super-class and continues along a scan line until an element classed as a three is encountered, after which all data is ignored. It is thus necessary that each scan line of data contain only one continuous block of data for interface analysis. Figure 6 illustrates this restriction. If it is necessary to exclude an area which is not convex with respect to the scan lines (i.e., where an excluded area interrupts a scan line, such as that shown in figure 6b), the problem may often be alleviated by changing the class of the offending area to that of the surrounding area, thus eliminating any interface within the area which is to be excluded. This restriction will be eliminated in a future release of the software.

The seventh step of the analysis is the determination of the geographic parameters which relate the scanner data to the actual surface scene. This relation requires geometric correction for distortion inherent in the data and determination of the scale of the data.

The problem of geometric correction is somewhat different when considering the interface detection/measurement analysis than when approaching a straightforward mapping problem. For this measurement, the exact positioning of a given feature is not the primary consideration,

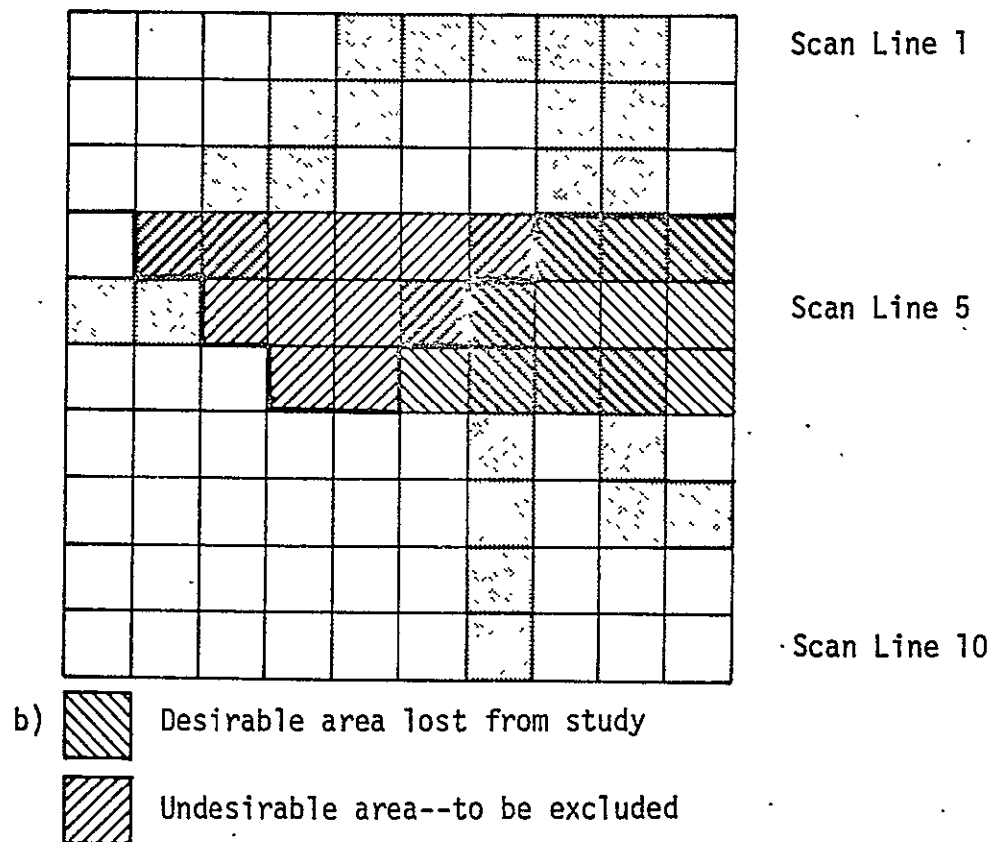
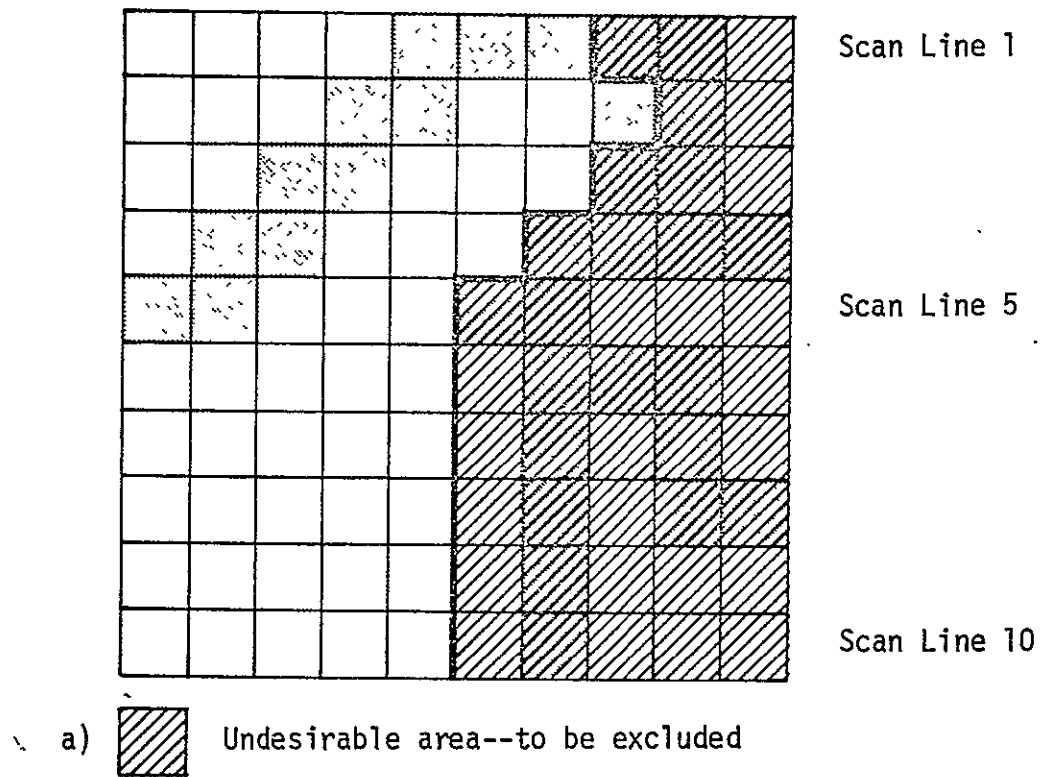
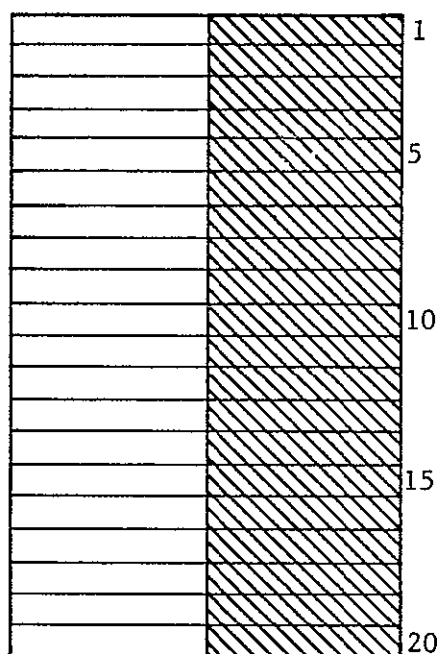


Figure 6. - Restriction on exclusion of data.

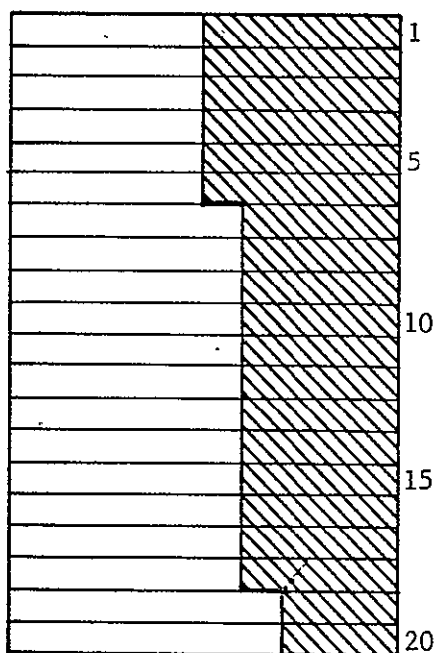
A scan line of data must consist of a single block of data to be processed uninterrupted by excluded data. Data may be excluded at the beginning or end of a scan line.

whereas the principle consideration is that straight lines remain straight and curved lines retain their original curvature. This is a very difficult problem when working with aircraft data when the roll correction of the scanner fails to fully compensate for the aircraft roll, or the altitude, heading, or speed varies. The problem with aircraft data will not be addressed in this document.

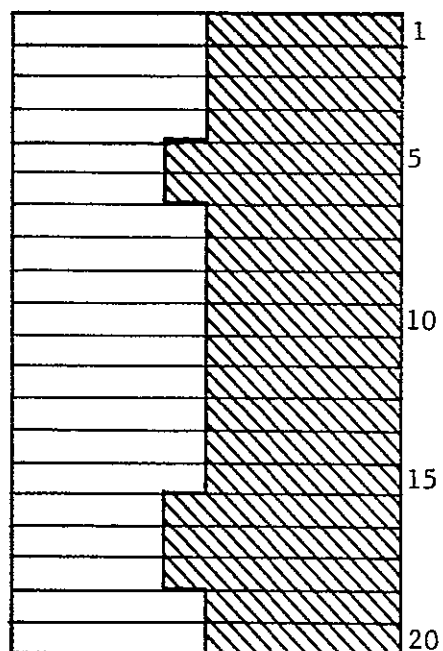
The use of satellite data requires consideration of the problem introduced by the earth's rotation beneath the satellite. The distortion is manifest as an apparent shifting of scan lines to the east for satellites in a descending polar orbit, such as LANDSAT. The effect of this distortion on the interface measurement is to shorten features which are oriented in a generally northeast to southwest direction and lengthen features oriented in a generally northwest to southeast direction. The correction for this skewing of the image is dependent upon the altitude of the satellite, the latitude of the study area, and the scan rate of the sensor. It is typically made by shifting entire scan lines to the west as the satellite proceeds southward along its orbital path. Use of LANDSAT data requires consideration of a special feature of the multispectral scanner (MSS) flown on that platform. The LANDSAT MSS collects six scan lines of data simultaneously with the result that this distortion is introduced into the image only at intervals of six scan lines. Correction for skew is performed by periodically shifting the data to the west while working south in the image; but the correction must not be made within this six line unit, as its geographic integrity is not disturbed by the earth rotation. All corrections for skew in the LANDSAT data must be made between these units, as illustrated in figure 7. If the corrections



a) A feature as it appears on the earth surface and in properly corrected satellite-borne scanner data.



b) The same feature as it appears in uncorrected scanner data from a satellite platform.



c) The same feature as it appears in data which has been corrected without considering the six scan line unit.

Figure 7. - Correction for rotation of earth beneath LANDSAT.

are made within the six line unit, linear features transversing either the proper shift point, the erroneous shift point, or both will normally be lengthened.

Figure 7 shows schematically an interface between two features as they might appear on the earth surface and in LANDSAT data. In the first part of the figure, the actual feature is shown. In the second, the feature is shown as it appears in uncorrected LANDSAT MSS data, as it would be extracted from the CCT's on which the data are recorded and provided to the user. Figure 7c was constructed by shifting this raw CCT data one element to the west every 11 scan lines, the proper rate of correction based on a statistical analysis of an entire frame of data. While the image as a whole will be portrayed accurately with this correction, with no net displacement or rotation of the feature introduced, the feature itself will be distorted. Proper correction would shift the data one element to the west every 12 scan lines, with one additional westward shift introduced every 132 scan lines, to give 12 shifts in 132 scan lines just as the simpler method does.

The scale of the imagery is determined from the physical dimensions of an individual picture element on the surface of the earth. When this is found, the contributions of the various interface types can be computed.

The two dimensions of the picture element and the skew correction factor (expressed as the frequency at which additional westward shift of one pixel must be made) are best determined directly from the image, as opposed to theoretical calculations based on sensor and platform characteristics. This is done by locating points both on accurate

maps and in the imagery, measuring the distance separating the points on the map, and using these distances together with the separation of the points in the image in terms of scan lines and scan elements in a least squares error analysis. An equation of the form

$$D = \sqrt{[S_V \Delta V]^2 + [S_H (\Delta H - S_K \Delta V)]^2}$$

is used, where D is the distance between the points, S_V is the vertical scale factor (i.e., the dimension of the picture element perpendicular to the scan direction), ΔV is the number of scan lines between the points in the image, S_H is the horizontal scale factor (the dimension of the picture element along the scan line), ΔH is the number of elements along the scan line separating the points in the image, and S_K is the skew correction factor. Only the two scale factors are used directly in the interface analysis software, but when satellite data is used, the skew correction must be applied beforehand.

The points should be taken in the same portion of the data that will be analyzed. This is important because the size of the picture element will vary with scan angle in almost any kind of data. The LANDSAT MSS data has a small distortion along the scan lines introduced as a result of the non-linear rate of motion of the oscillating mirror which scans the earth scene. Aircraft data are usually acquired with such large scan angles that one cannot assume a constant instantaneous field of view of the sensor. This latter problem should be corrected by rectifying the data before the interface analysis is performed. When large areas are to be subjected to the analysis, they should be

broken down into units for which constant scale factors can be assumed, and the analysis should then be performed on the individual segments and the results combined.

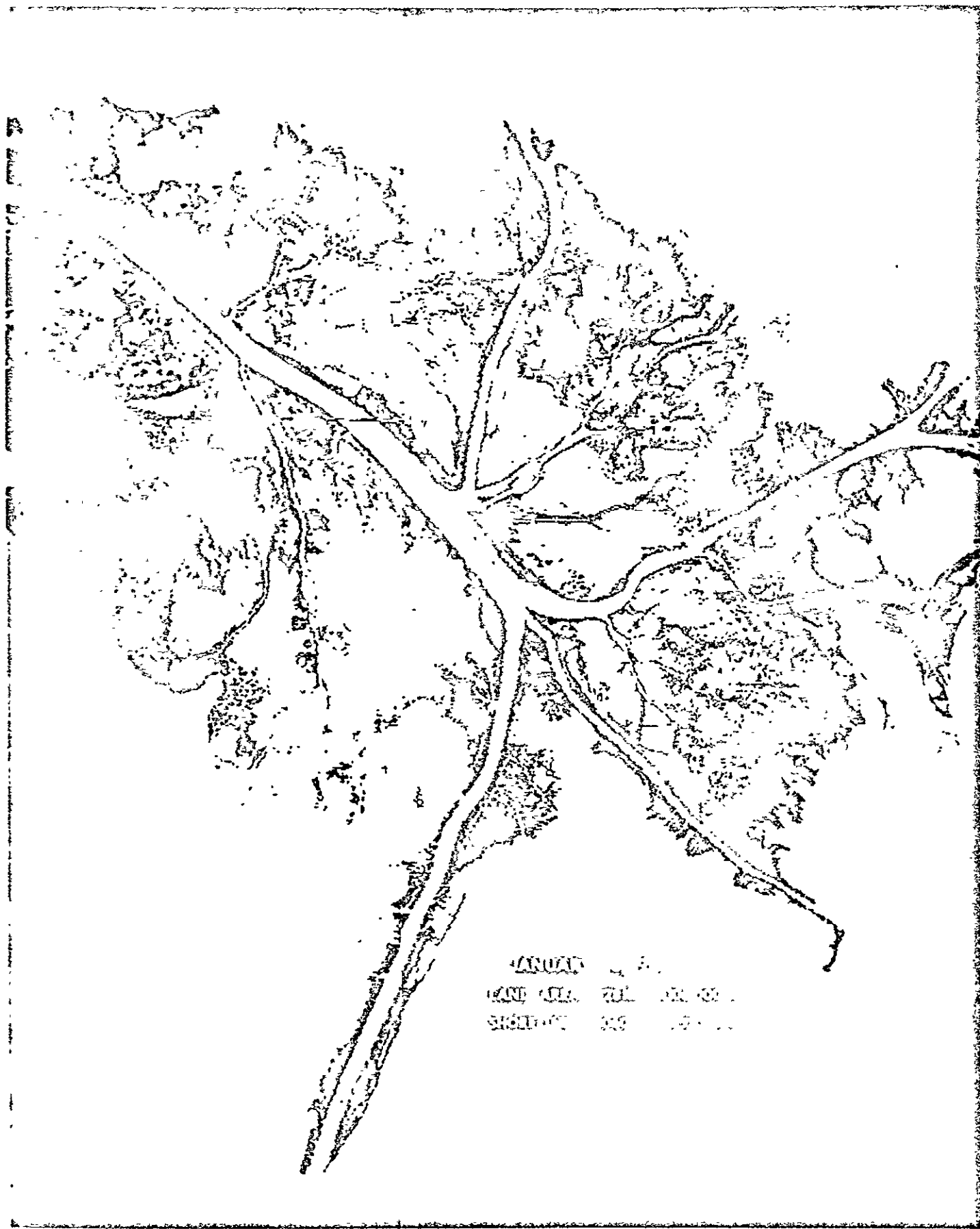
The classified data from LANDSAT are normally processed at ERL using a computer program known as SKEWCOR, which makes use of the skew correction parameter computed above to perform the proper shifting of data to compensate for the earth's rotation beneath the satellite. This program is to be used only temporarily and will be superseded by a more general and more accurate geographic correction and reference program in the future. SKEWCOR is limited to use on data acquired at intermediate latitudes only, but this limitation will not be present when the general program is incorporated into the processing system. Minor modification to SKEWCOR will allow its use at different latitudes.

After correcting for distortion (processing step 8), the data is ready to be processed by the interface detection and measurement program, SHORL (step 9). The program is loaded with the scale factors and the codes corresponding to the classes to be included in each of the two super-classes. Any classes not included in either super-class are disregarded, as they are included in the class which the processing ignores. The scan line number with which processing is to begin and the number with which it is to terminate may be read in; if the entire scan is not to be processed, the element numbers within the scan line between which the data are to be processed can also be limited. Data before and after these end points are not considered. If aircraft data are being used, the start and stop scan lines may be specified in terms of the time of acquisition rather than the scan line numbers.

The interface detection and analysis program SHORL then reads the input data tape, and a display of the two classes and the interface is generated on a second magnetic tape with an identical format. The length of the interface between the two classes and the area of each is computed and listed. Figure 8 is an example of the display product, which is generated as the final step of processing.

Figure 8. - Display product (See following page 26A)

This display was generated by the interface analysis program using data acquired over the active delta of the Mississippi River on January 16, 1973 by LANDSAT I. The yellow area represents the interface which has been detected and measured.



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V. DEMONSTRATION

Discussion with personnel of the Geological Survey of Alabama revealed the need for an objective measurement of the Alabama shoreline. Several estimates had been made, but there were large discrepancies among them. Use of satellite data for measurement of the shoreline, via the computer implemented interface analysis algorithm, provided the opportunity to make the measurement based on defined objective criteria. The resolution of the data is defined by the resolution of the LANDSAT multispectral scanner, and the geographic limits of the analysis can be explicitly defined. Perhaps most important, the element of human error in the manipulation of the opisometer, an important consideration in the conventional manual measurement, is completely eliminated.

This section of the report is a step-by-step description of the work performed in developing the shoreline analysis for the State of Alabama. The time required for each step is only approximate, as the personnel involved in the work were assigned to other tasks at the same time, and some modifications to the procedure and software were instituted during the period in which the analysis was performed.

A. Data Selection (Processing Step 1)

To simplify problems with floating or overhanging vegetation, it was decided that data from winter periods would be used in the analysis. The area to be studied covered the entire southern portion of the State of Alabama. One of the LANDSAT groundtracks passes through the center of the area, making the data available on a

single data frame. The film images covering the area during the desired period were examined and two were selected, one from December 1972 and the other from December 1973. The two frames are shown in figure 9. Conditions were somewhat different for the two dates, as river discharges were considerably greater in December 1972 than in December 1973. Analysis of the shoreline under these two conditions should represent two extreme cases, because small streams are not detected in one set of data but are detected in the other, as swelling of small streams may bring them into the size range that can be resolved by the scanner. After selecting the data, computer compatible magnetic tapes for the two frames were ordered. Tapes 2, 3, and 4 of the four tape set were required to cover the study area.

This first phase of the analysis required four hours' effort on the part of the investigator.

B. Classification (Processing Steps 2, 3, 4, and 5)

A simple two category classifier was used in this demonstration project. The classification technique is a land/water discriminator developed at the Johnson Space Center for use with LANDSAT data and modified by ERL. The classifier, known as Water Search (Johnson Space Center, 1973), utilizes the intensity measurements in the green band ($0.5 - 0.6 \mu\text{m}$) and in one of the infrared bands ($0.8 - 1.1 \mu\text{m}$). This infrared band alone provides a very good definition of land and water because water strongly absorbs radiation in that spectral region while typical land features strongly reflect this radiation. The spectral signature of water is defined as all values in the



LANDSAT IMAGE, DECEMBER 1972



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LANDSAT IMAGE, DECEMBER 1973

Figure 9. - LANDSAT frames for Alabama shoreline study

infrared band less than a particular value. This value is a function of the intensity in the green band. The intensity of green light reflected from the area being classified serves to adjust this infrared intensity value, the decision point, for varying turbidity levels of water, a factor which can cause recognition problems in areas typified by muddy river discharges or marshes.

The spectral signature for water was developed as the first phase of the classification. Areas known to be land and areas known to be water were located in the image. Marshland, urban areas, agricultural regions, and forestlands provided the "not-water" spectral information while water from the Gulf of Mexico, Mississippi Sound, upper and lower Mobile Bay, and marsh areas provided the information on the appearance of the water in the data. A graph with axes representing the green band intensity and the infrared band intensity was developed, with data points corresponding to land features differentiated from those which corresponded to water features. A line was then drawn through the data which best separated the two sets of points. This line defined the discriminator for the classification of the entire data set, which was accomplished by comparing each pixel to the curve and classifying those falling to the right of the curve as land, those to the left as water.

The classifier was applied to the areas being used to develop the discriminator with the results showing excellent agreement with interpretation of aerial photography. The classifier was then applied to the complete data set, and a classified image was then

produced. The complete procedure was performed for both data sets (1972 and 1973), as spectral signatures cannot be used on data sets other than the one from which they were derived. These images were compared carefully with aerial photography acquired in February 1973 (NASA Earth Resources Aircraft Project, Flight Number 73-023). Considering the fact that river conditions were so different for the two dates, excellent agreement between the two LANDSAT data sets and the photography was achieved. The classification of the data was a rather lengthy process, as the determination of spectral signatures required approximately 30 hours' effort on the part of a technician and 5 hours on the part of the investigator. The classification of the entire data set required 4 hours by the DAS operator.

C. Isolation (Processing Step 6)

The requirement of the Geological Survey of Alabama was for a measurement of the tidal shoreline. The development of the analysis within that constraint required that all of the land/water interface outside of the tidal area within the state be eliminated as well as all interface outside the Alabama state boundaries. Using a display of one of the images resulting from the land/water classification, survey personnel delineated the area to be analyzed by drawing a line on the image defining the study area. This is illustrated in figure 10.

This limit was then transferred to the computer compatible data using the DAS interactive update program. This procedure reduced all data outside the study area to a unique value that would be

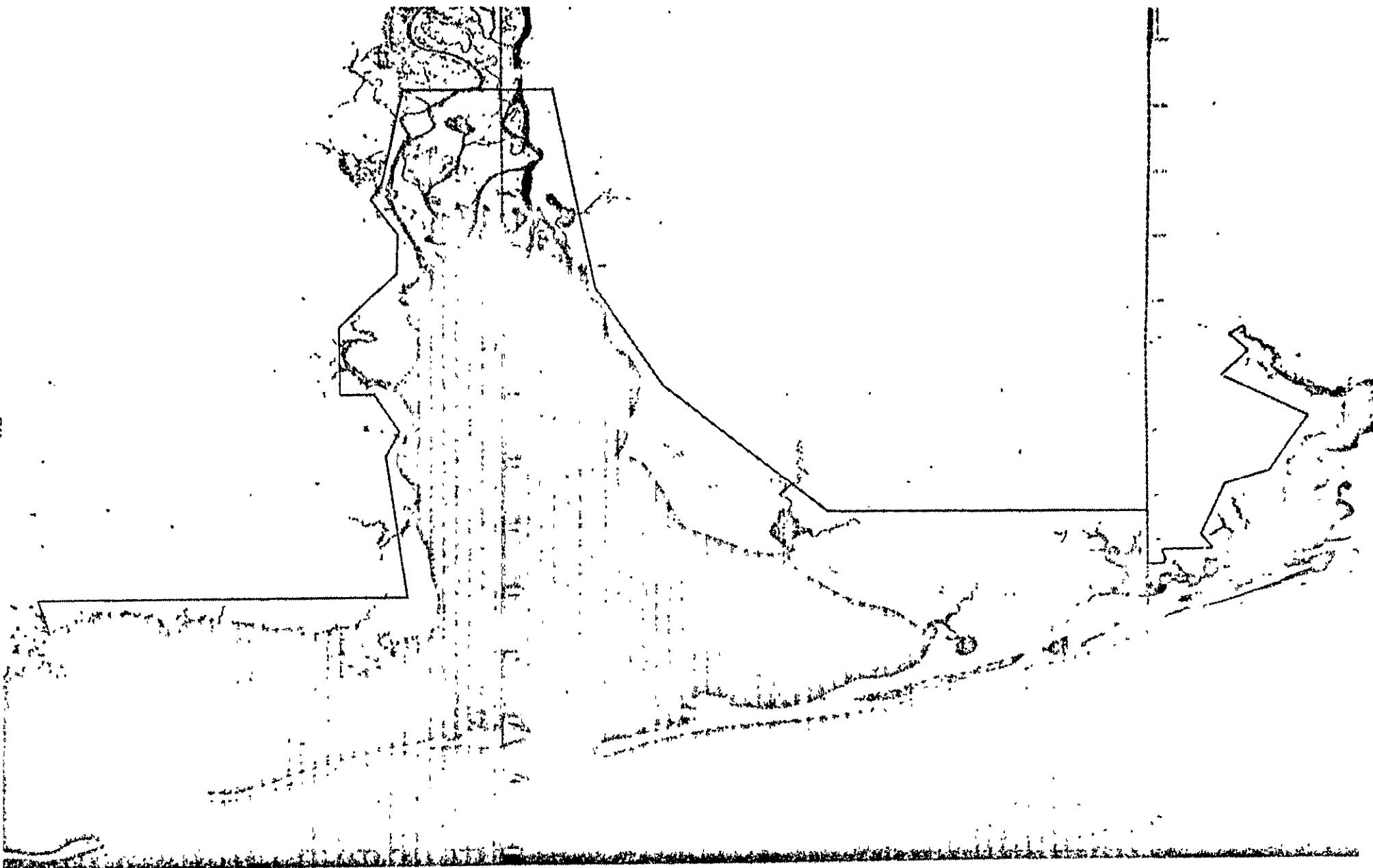


Figure 10. - Delineation of area to be analyzed.
Area to be subjected to analysis was
delineated by state personnel.

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excluded from the interface analysis. A problem was encountered in the Perdido Bay area where scan lines had to be interrupted to exclude an intruding land mass belonging to Florida. This was handled by changing this Floridian peninsula to water in this data, thus eliminating all shoreline which would have been contributed by this area.

Delineation of the study area required approximately three hours' effort on the part of the investigator and one individual from the Geological Survey. The interactive data manipulation required 18 hours by a technician and a DAS operator and evaluation of the intermediate product required one hour's effort by the investigator.

D. Scale Determination (Processing Step 7)

Using the land/water thematic generated by the Water Search program, a set of landmarks was located. The scan line number and element within the scan were determined for each landmark using the thematic, while the actual distances separating the points were measured on NOS Chart 1266. Eight points were identified and five inter-point distances were measured on the chart. The picture element dimensions were then determined to be 57.34 meters along the scan line and 80.80 meters perpendicular to the scan line for the 1972 data and 57.94 meters and 80.04 meters for the 1973 data.

The determination of the picture element dimensions required six hours' effort by a technician.

E. Geometric Correction and Interface Measurement
(Processing Steps 8, 9 and 10)

The correction for the rotation of the earth beneath the satellite was performed using SKEWCOR. The number of elements to be processed in each scan line was limited at this stage of processing to eliminate the non-video information (calibration data not used in this analysis) appearing at the end of the second and third tapes.

After the skew correction was performed, the three tapes for each date were processed by the interface analysis computer program. The results of the analysis for all three tapes for each date are summarized in table I. After the analysis was performed on the complete data set for each date, the interface display tapes generated by the analysis software were output on an electrostatic printer/plotter. The products are presented in figures 11a and 11b, where the land is shown as white, the water light gray, and the shoreline black. Only the area included in the study is shown in the final products.

The skew correction and actual interface analysis required approximately 10 hours of the technician's time while output of the display products was a two hour process, requiring the computer operator only. About three hours were required by the investigator and technician to quality check the final product. Table II contains the complete time requirements for this demonstration project, including the analysis of both frames of data.

TABLE I. - ALABAMA TIDAL SHORELINE LENGTH

DATE	TAPE	SHORELINE LENGTH (Kilometers)
1972	2	732.5
1972	3	557.2
1972	4	162.8
1972	STATE TOTAL	1451.5
1973	2	136.5
1973	3	795.4
1973	4	230.7
1973	STATE TOTAL	1162.6
MEAN	STATE TOTAL	1307

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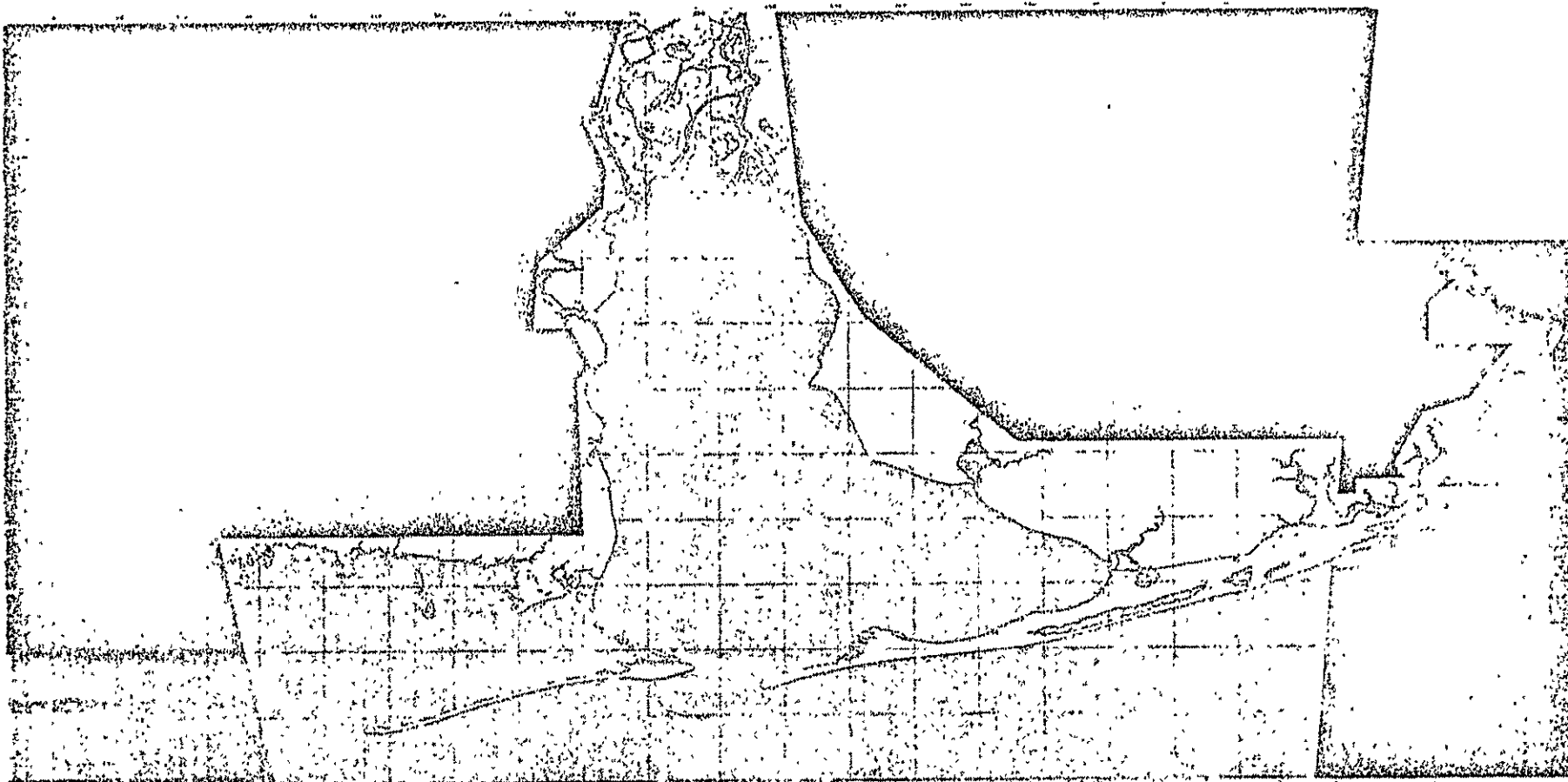


Figure 11a. - Alabama Shoreline Analysis Display Product - 1972

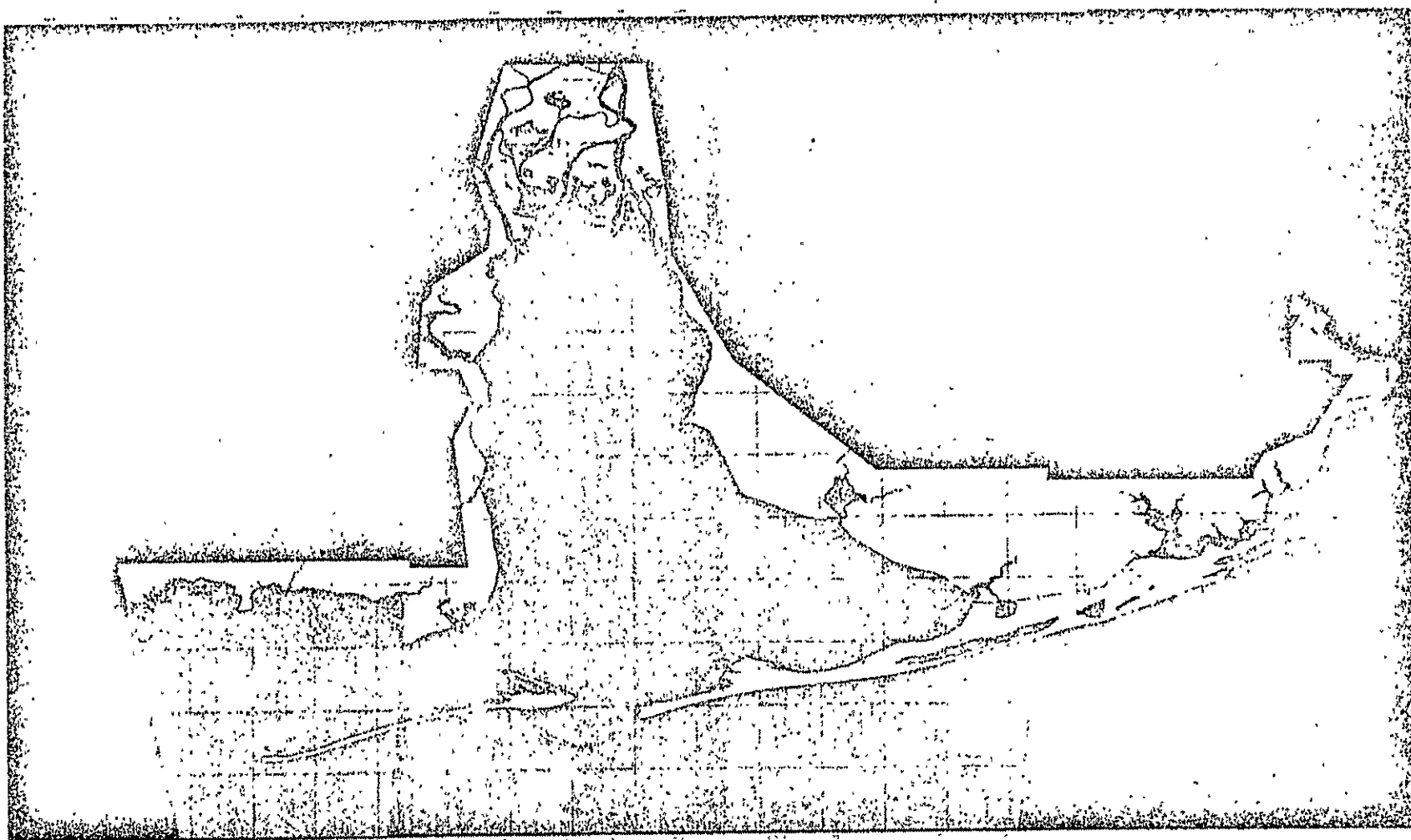


Figure 11b. - Alabama Shoreline Analysis Display Product - 1973

TABLE II. - MANHOUR EFFORT REQUIRED FOR ANALYSIS OF ALABAMA TIDAL SHORELINE

	DATA SELECTION	CLASSIFICATION	ISOLATION	SCALE	ANALYSIS	TOTAL
INVESTIGATOR	4	5	4	0	3	16
TECHNICIAN	0	30	18	6	13	67
DAS OPERATOR	0	4	18	0	2	24
GEO. SURVEY	0	0	3	0	0	3
TOTAL	4	39	43	6	18	110

REFERENCES

Johnson Space Center, 1973. Procedure Manual for Detection and Location of Surface Water Using ERTS-1 Multispectral Scanner Data, JSC, Houston, Texas.

Whitley, Sidney L., A Procedure for Automated Land Use Mapping Using Remotely Sensed Multispectral Scanner Data, NASA TR R-434, JSC, Houston, Texas.